Patent Abstracts of Japan

PUBLICATION NUMBER : 06140632
PUBLICATION DATE : 20-05-94

APPLICATION DATE : 27-10-92
APPLICATION NUMBER : 04288048

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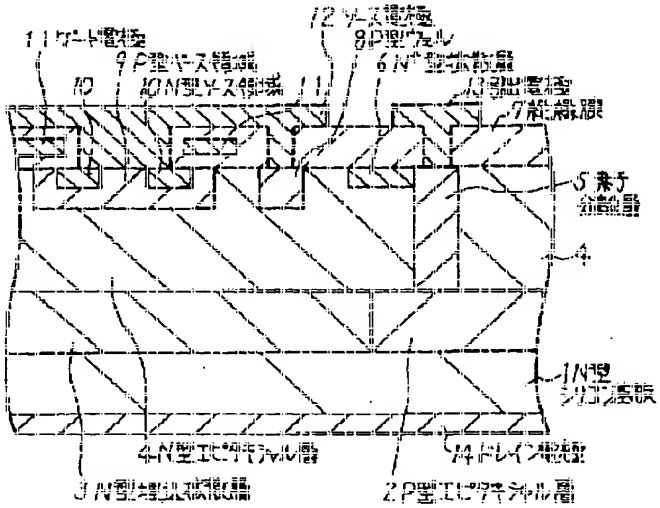
INT.CL. : H01L 29/784

TITLE : SEMICONDUCTOR DEVICE



ABSTRACT : PURPOSE: To prevent the destruction of a vertical type MOSFET due to a counter-electromotive force occurring when an inductive load is driven by providing the vertical type MOSFET of a power IC having a vertical type MOSFET with a built-in diode having a low reverse breakdown voltage.

CONSTITUTION: In a vertical type MOSFET of a power IC in which a p-type epitaxial layer 2 and an n-type epitaxial layer 4 are disposed and the vertical MOSFET and a control circuit are isolated from each other by an element isolation layer 5, a diode having a low reverse breakdown voltage is created by forming an n^+-type diffusion layer 6 while it is in contact with the element isolation layer 5 within the n-type epitaxial layer 4.

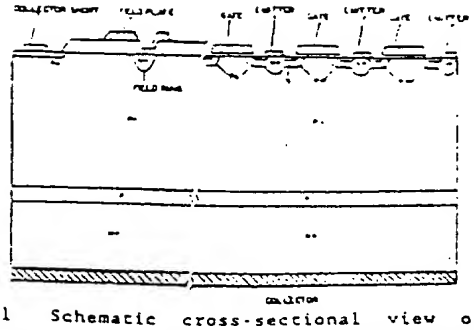


Fig. 1 Schematic cross-sectional view of the collector-shorted, p-channel, vertical insulated gate bipolar transistor.

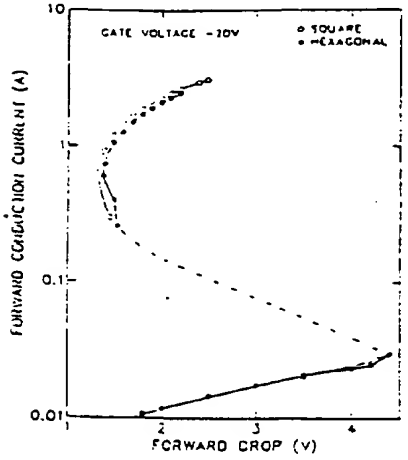


Fig. 2 Forward conduction current as a function of forward voltage drop for collector-shorted vertical IGBT with square and hexagonal cell designs. A linear I-V region before the onset of conductivity modulation can be seen.

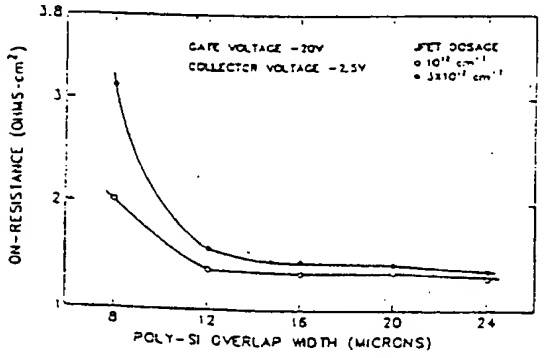


Fig. 3 On-resistance of the MOSFET region at collector voltage of -2.5V as a function of poly-Si overlap distance.

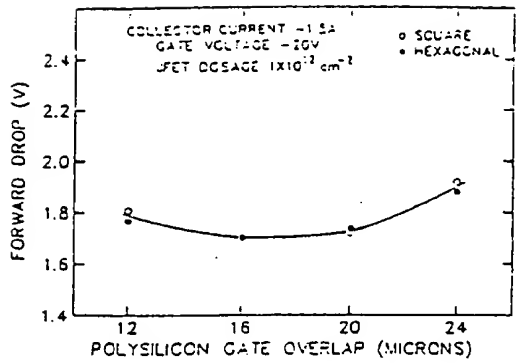


Fig. 4 Forward voltage drop at -1.5A (-214A/cm^2) vs. poly-Si gate overlap width.

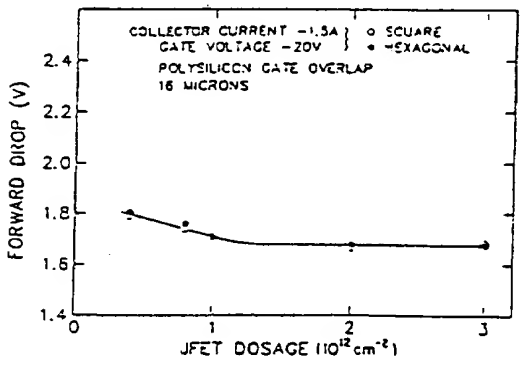


Fig. 5 Forward drop as a function of JFET dosage, ranging from 5x10^{11} to 3x10^{12} cm^{-2}.

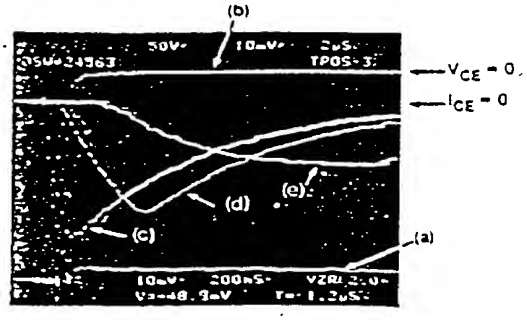


Fig. 6 Turn-on current and voltage waveforms for a collector-shorted, p-IGBT. (a) Total collector current (0.2A/div.) and (b) collector voltage (50V/div.). Collector short current (0.1A/div.) for (c) 0, (d) 1KΩ and (d) 4KΩ turn-on resistors. Time scale: 200 ns/div.

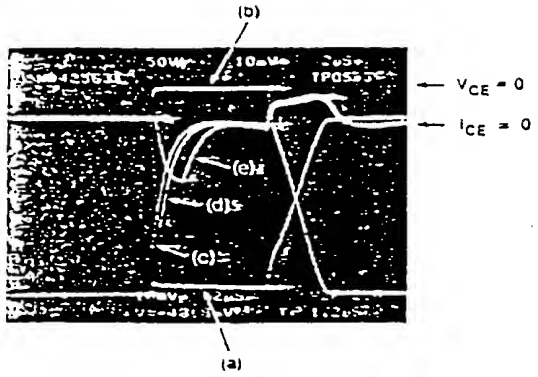


Fig. 7 Turn-on and turn-off current and voltage waveforms for a collector-shorted, p-IGBT. Same current and voltage scales and designations as those in Fig. 6. Time scale: 2 μs/div.

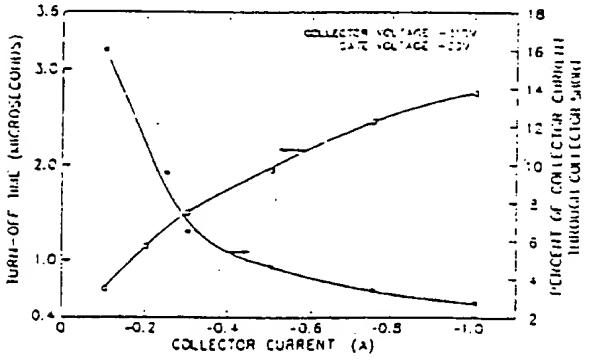


Fig. 8 Turn-off time of collector-shorted vertical IGBT vs. turn-off current for a hexagonal cell design with poly-Si gate overlap of 16μm. The fraction of the collector current that goes through the short is also shown to indicate that the increase in turn-off time with increasing current is due to increased minority carrier current.

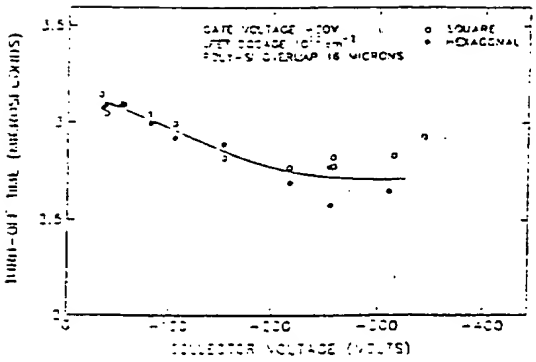


Fig. 9 Turn-off time vs. collector voltage for collector-shorted vertical IGBT with square and hexagonal cell design and poly-Si gate overlap of 16μm.

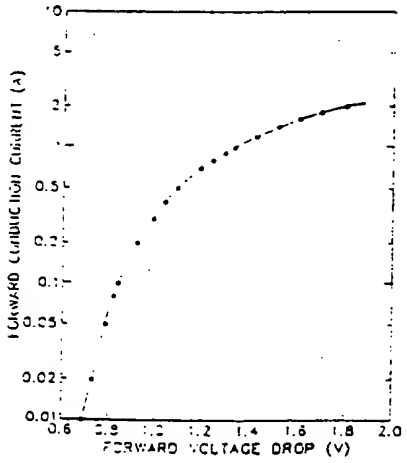


Fig. 10 Forward I-V characteristics for the integral diode formed between the p+ collector short and the deep n+ short in the DMOS cells.